

CLAIMS

1. A method of determining an acoustic velocity in a bone, comprising:
 transmitting, from a location adjacent a first in-vivo bone, an acoustic wave having a wavelength about the same or smaller than a cross-section of the bone, which cross-section is perpendicular to a main travel direction of said acoustic wave in said bone;
 receiving said acoustic wave at a location adjacent a second in-vivo bone; and
 determining an acoustic velocity of at least a portion of at least one of the first and second bones, from a travel time of said wave through said first and second bones and at least one joint between said bones.
2. A method according to claim 1, wherein said locations have an unknown positional relationship.
3. A method according to claim 1, wherein said locations have a known positional relationship.
4. A method according to claim 1, wherein said receiving and said transmitting comprise receiving and transmitting using mechanically coupled acoustic elements.
5. A method according to claim 1, wherein said receiving and said transmitting comprise receiving and transmitting using mechanically uncoupled acoustic elements.
6. A method of determining a characteristic of a bone, comprising:
 transmitting, from a location adjacent a first in-vivo bone, an acoustic wave having a frequency of at least 20kHz;
 receiving said acoustic wave at a location adjacent a second in-vivo bone; and
 determining at least one acoustic characteristic of at least a portion of at least one of the first and second bones, from a travel time of said wave through said first and second bones and at least one joint between said bones.
7. A method according to claim 6, wherein said acoustic characteristic comprises acoustic velocity.
8. A method according to claim 6, wherein said acoustic characteristic comprises acoustic attenuation.

Replaced
by Article 34

1-30
5-53

4-12-2004

acoustic
bone

5,396891

velocity
at

6,651.30

bone
velocity

acoustic
velocity
in
bone,

4-19-03

Scanlon
5863005

Red

9. A method according to claim 6, wherein said acoustic characteristic comprises polarization properties.
- 5 10. A method according to any of claims 7-9, wherein said acoustic characteristics are determined for a plurality of wavelengths, to estimate a frequency dependent variation thereof.
11. A method according to any of claims 1-10, wherein the joint is articulated.
- 10 12. A method according to any of claims 1-10, wherein said first and second bones are interconnected by at least a third bone and wherein said at least one joint comprises at least one joint interconnecting said first bone and said at least third bone and at least a second joint interconnecting said at least third and said second bones.
- 15 13. A method according to claim 12, wherein said at least a third bone comprises at least two bones interconnected by a joint, through which the wave travels.
14. A method according to any of claims 1-13, wherein said wave travels between an elbow and a finger.
- 20 15. A method according to any of claims 1-13, wherein said wave travels between an elbow and a knuckle.
16. A method according to any of claims 1-13, wherein said wave travels between a knee and an ankle.
- 25 17. A method according to any of claims 1-13, wherein said wave travels between a trochanter and an pelvis.
- 30 18. A method according to any of claims 1-13, wherein said wave travels between two hips.
19. A method according to any of claims 1-13, wherein said wave travels along a rib.

20. A method according to any of claims 1-13, wherein said wave travels along a portion of a skull.
21. A method according to any of claims 1-13, wherein said bones comprise spinal
5 vertebra.
22. A method according to any of claims 1-21, wherein receiving the acoustic wave comprises receiving at least a second acoustic wave, which second wave has a path substantially overlapping a path in bone of said first wave for a significant portion of its
10 length.
23. A method according to claim 22, wherein the two waves are received using a single receiver and are generated at two different locations.
24. A method according to claim 22, wherein the two waves are received using two
15 receivers and are generated at a single location.
25. A method according to claim 24, wherein a line interconnecting said two receivers is not parallel to a surface of bone underlying the two receivers.
20
26. A method according to any of claims 22-25, wherein said travel time comprises a relative travel time of said two waves.
27. A method according to any of claims 22-26, wherein said two waves are generated
25 substantially simultaneously.
28. A method according to any of claims 22-26, wherein said two waves are generated as a single source wave.
29. A method according to any of claims 22-26, wherein said two waves are generated at a
30 time delayed relative to each other.
30. A method according to any of claims 1-29, comprising repeating said transmitting and said receiving for at least a second acoustic wave, traveling in a direction substantially
35 opposite a traveling direction of said wave, to determine local acoustic bone characteristics at

an area which is traversed by both of said waves.

31. A method of determining an acoustic bone characteristic, comprising:

transmitting an acoustic wave from a first location adjacent a first bone;

5 receiving said acoustic wave at at least two locations adjacent a second bone, near each other, said locations being significantly distanced from said first location, such that said wave travels substantially overlapping paths from said first location to a location near said two locations; and

10 determining an acoustic characteristic of the bone adjacent said two locations from said received signals.

32. A method of determining an acoustic bone characteristic, comprising:

transmitting an acoustic wave from a first location adjacent a body;

15 receiving said acoustic wave at at least two locations adjacent a bone, near each other, said locations defining a line non-parallel to the bone surface and significantly distanced from said first location, such that said wave travels substantially overlapping paths from said first location to a location near said two locations; and

determining an acoustic characteristic of the bone adjacent said two locations from said received signals.

20 33. A method according to claim 32, wherein said first location is adjacent said bone.

34. A method according to claim 32, wherein said first location is adjacent a different bone.

25 35. A method according to any of claims 32-34, wherein said transmitting and said receiving utilize two mechanically uncoupled elements.

30 36. A method according to any of claims 32-34, wherein said transmitting and said receiving utilize two mechanically coupled elements.

37. A method according to any of claims 32-36, wherein said characteristic comprises a trabecular velocity of the bone.

38. A method according to any of claims 32-36, wherein said characteristic comprises a cortical velocity of the bone.
39. A method according to any of claims 32-36, comprising further receiving a second
5 wave at or near said two locations from a second source at a second location, significantly displaced from said two locations and using said received second wave in determining said characteristic.
40. A method according to claim 39, wherein said second significantly displaced source is
10 on a substantially opposite side of said at least two locations, from said first location.
41. A method according to any of claims 32-40, wherein all of said locations are not collinear.
42. A method according to any of claims 32-40, wherein all of said locations are not
15 coplanar.
43. A method of determining a property of a bone, comprising:
transmitting an acoustic wave having a frequency of above 20 kHz along an axis of
20 said bone, through at least a core thereof;
receiving said wave after said travel; and
analyzing said received wave to determine at least one acoustic characteristic of said bone.
44. A method according to claim 43, wherein said acoustic characteristic comprises an
25 acoustic velocity.
45. A method of bone velocity measurement, comprising:
transmitting at least one acoustic wave into a bone at a first location;
30 receiving said wave at at least two locations outside said bone, after it passes through said bone, wherein said first location and said at least two locations are not collinear; and
determining a trabecular velocity of said bone from said received wave.
46. A method according to claim 45, wherein said bone comprises an ankle bone.

47. A method of determining an acoustic velocity in a bone, comprising:
transmitting an acoustic wave from a first location adjacent an in-vivo bone;
receiving said acoustic wave at a second location adjacent the bone, which second
5 location has an unknown positional relationship relative to said first location; and
determining an acoustic velocity of at least a portion of said bone, from a travel time of
said wave between said first and said second locations.
48. A method according to claim 47, wherein receiving comprises receiving using two
10 receivers.
49. A method according to claim 48 and including a difference in time of receipt of the
wave by said two receivers, wherein determining comprises determining from said time
difference.
- 15 50. Apparatus for determining an acoustic velocity in at least a portion of an in-vivo bone,
comprising:
a transmitter for generating acoustic signals;
at least one receiver, mechanically uncoupled to said transmitter, for receiving said
20 generated acoustic signals after they travel through a bone; and
circuitry for determining an acoustic velocity in said bone responsive to said received
wave.
51. Apparatus according to claim 50, wherein said circuitry determines said velocity
25 responsive to a relative arrival time of said wave.
52. Apparatus according to claim 50 or 51, wherein said at least one receiver comprises at
least two receivers.
- 30 53. A method according to claim 52 and including a difference in time of receipt of the
wave by said two receivers, wherein determining comprises determining from said time
difference.